

THE EISENHOWER LIBRARY



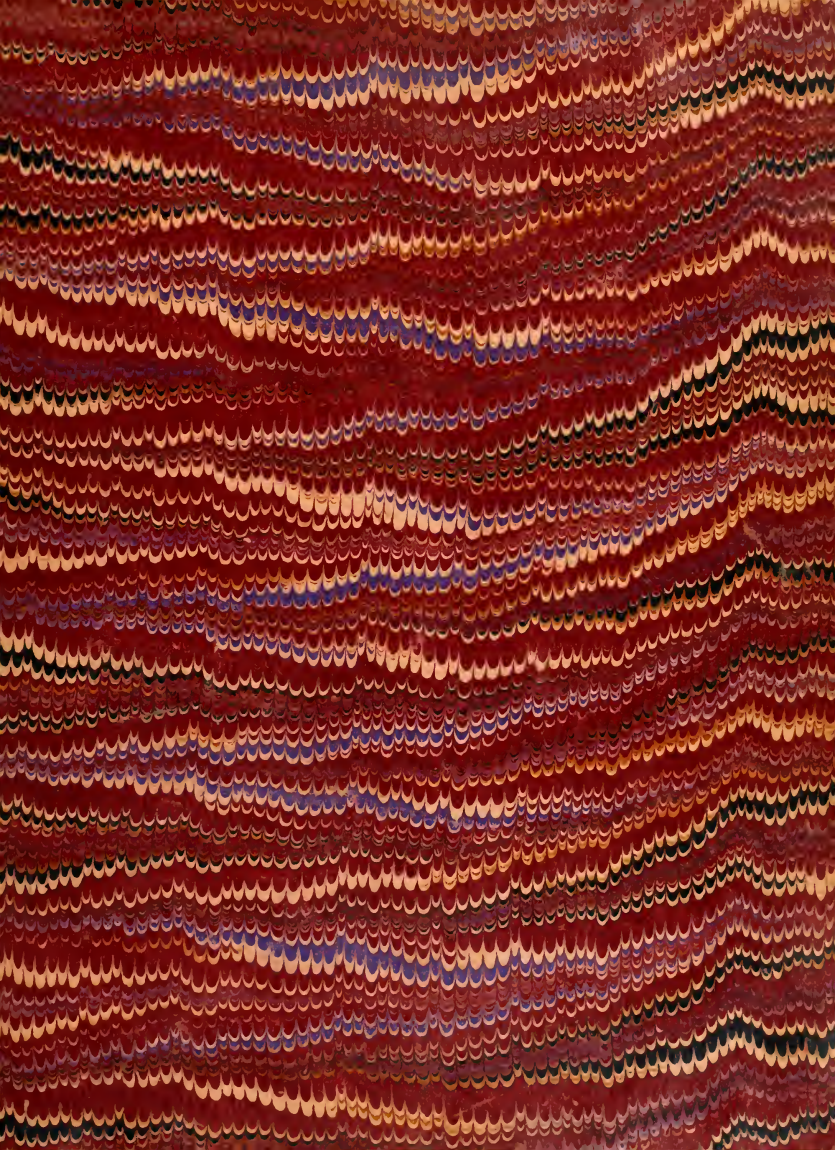
3 1151 02721 3374

101 184

Library



Johns Hopkins University





















THE ACTION OF SUBSTITUTED AMMONIAS  
OF THE ALIPHATIC SERIES ON THE CHLORIDES OF  
ORTHO-SULPHOBENZOIC ACID.

-----

Dissertation

Submitted to the Board of University  
Studies of the Johns Hopkins University in  
Conformity with the Requirements for the  
Degree of Doctor of Philosophy.

by

Friend E. Clark.

--OC--

Baltimore,  
1902.



## Contents.

	Page.
Acknowledgement -----	iv
Introduction -----	1
Previous Work on the Chlorides and Substituted	
Ammonias -----	5
Preparation of Material -----	8
Acid Ammonium Salt of Orthosulphobenzoic Acid ---	10
Neutral and Acid Potassium Salts of Orthosulpho-	
benzoic Acid -----	11
Symmetrical Chloride -----	12
Unsymmetrical Chloride -----	14
Purification of Petroleum Ether and Crystalliza-	
tion of the Chlorides -----	15
Method Employed in Handling the Amines -----	17
Action of Methylamine -----	18
I. On the Symmetrical Chloride -----	18
Methyl Benzoic Sulphinide -----	20
Methylamonium Salt of Orthosulphoben-	
zoic Acid -----	23
Potassium Orthomethylsulphaminebenzoate--	25
Barium Orthomethylsulphaminebenzoate----	26
Orthomethylsulphaminebenzoic Acid -----	29



Orthomethyltoluenesulphone Amide -----	29
Action of Aqueous Amine on the Symmetri-	
cal Chloride -----	30
II. On the Unsymmetrical Chloride -----	32
Infusible Dimethylamide of Orthosulpho-	
benzoic Acid -----	32
Action of Ethylamine on the Chlorides----	36
Historical -----	36
I. Symmetrical Chloride -----	37
Ethyl Ester of Benzoic Sulphinide -----	47
Potassium Orthoethylsulphaminebenzoate---	39
Barium Orthoethylsulphaminebenzoate -----	39
Ethylammonium Salt of Orthosulphobenzo-	
ic Acid -----	40
II. Unsymmetrical Chloride-----	41
Infusible Diethylamide of Orthosulpho-	
benzoic Acid -----	43
Action of Liquid Ethylamine on the Un-	
symmetrical Chlorides -----	44
The Action of Dimethylamine on the Chlo-	
rides -----	45
I. Symmetrical Chloride -----	45





Tetramethylorthosulphaminebenzamide-----	45
Crystallographic Examination of Tetra- methylorthosulphaminebenzamide-----	47
II. Unsymmetrical Chloride-----	51
Conclusion-----	52
Biographical Sketch -----	54



### Acknowledgment.

This investigation was suggested by Professor Remsen, and the development of it carried on under his personal supervision. It is with pleasure that the author takes this opportunity to thank Professor Remsen for the assistance he has so willingly given him both in the lecture room and the laboratory throughout his University work. The author further wishes to express his appreciation of the instruction and inspiration he has received from Professor H.N.Morse. He is also indebted to Professor Renouf, Dr. Shattuck, Professor Clark, Dr. Matthews, Dr. Gilpin and Dr. Jones for instruction and advice.



THE ACTION OF SUBSTITUTED AMMONIAS ON THE CHLORIDES  
OF ORTHOSULPHOBENZOIC ACID.

--00--

Introduction

(1)

Since 1871 Professor Remsen has been much interested in orthosulphobenzoic acid and its derivatives, and since the founding of this University the rôle played by these compounds, as prepared and studied by Professor Remsen and his students, has not been inconsiderable. The article, to which reference has been made, had to do with the oxidation of the sulphonic acids of toluene by chromic acid. It was found that while chromic acid oxidizes paratoluenesulphone amide to parasulphamine benzoic acid, it does not convert orthotoluenesulphone amide into orthosulphaminebenzoic acid. At this time Remsen suggested the employment of potassium permanganate in alkaline solution as the oxidizing agent.

(2)

In 1879 Remsen and Fahlberg further investigated these oxidation products, and found that orthotoluenesulphone

---

(1) Amer. Jour. Sci. and Arts, V., 179, 274, 304;  
Annalen der Chemie (Liebig's) 178, 275.

(2) Amer. Chem. Jour. I., 496; Ber. d. Chem. Gesell. 12.  
469.

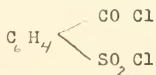




amide, when treated with an alkaline solution of potassium permanganate, yields the potassium salt of orthosulphaminebenzoic acid, which by treatment with hydrochloric acid loses the elements of water and passes to benzoic sulphinide. Benzoic sulphinide was also prepared by treating first the neutral potassium salt of orthosulphobenzoic acid with phosphorus pentachloride, and the chlorides (or chloride as they considered them) thus formed with ammonia.

(1)

Somewhat later Remsen and Dohme described "a colorless oil insoluble in water", prepared from acid ammonium orthosulphobenzoate and phosphorus pentachloride; to which they assigned the formula:

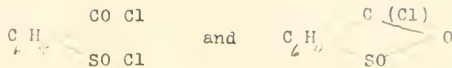


In 1891, while investigating the anilides of orthosulphobenzoic acid, Remsen and Coates (2) concluded that there are certainly two isomeric chlorides to which the anilides and analogous compounds can be referred. They compared them to the so-called symmetrical and unsymmetrical chlorides of phthalic acid, assigning to them the following

- 
- (1) Amer. Chem. Jour. 11.332; Inaug. Diss. J.H.U. (1889).  
 (2) Ibid. 17, 311, (1895); " " " (1891).



formula:



(1)

The work of Remsen and Kohler showed that the two chlorides are isomeric and that one possesses a definite crystalline form, the other, according to them, being an oil, that could not be crystallized. They ascribed to the solid chloride the symmetrical formula, and to the liquid chloride the unsymmetrical one. Remsen and Saunders obtained the so-called unsymmetrical chloride of orthosulphobenzoic acid in crystallized condition, and recorded its melting-point at  $21^{\circ}5 - 22^{\circ}5$ . This was later shown to be a mixture of the two chlorides.

Prior to the work of Remsen and Bucher no method for preparing either of the chlorides in pure condition had been described. On the basis of a reaction discovered by A.D. Chambers in this laboratory, Remsen and Bucher developed a method for preparing the symmetrical chloride - a method which in a somewhat modified form is used at present.

The observation of Chambers was that ammonia con-

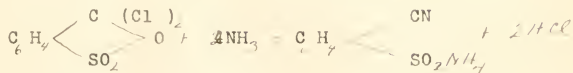
---

(1) Amer. Chem. Jour. 17, 330; Kohler, Inaug. Diss. J.H.U. 1891.

(2) Amer. Chem. Jour. 17, 347. Saunders, " " " 1894.



verts the unsymmetrical chloride into ammonium orthocyanobenzenesulphonate.



Comparatively recently, men working with Professor Remsen have more nearly perfected the methods for preparing the two chlorides; so that at present no serious difficulties are encountered in this direction.



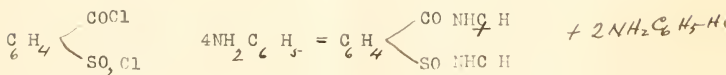
PREVIOUS WORK ON THE CHLORIDES AND SUBSTITUTED AMMONIAS

-----

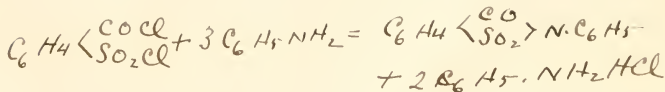
I. ACTION OF ANILINE -

(1)

Remsen and Coates showed that there are two compounds formed when aniline and the chlorides are brought together, according to the proportions of the reacting substances and the conditions of the reactions. For example, if an excess of aniline in aqueous solution is employed the symmetrical dianilide is formed thus:



If, however, the aniline is treated with the dry solid chloride orthosulphobenzoic acid is formed, showing that only one molecule of aniline takes part in the reaction.

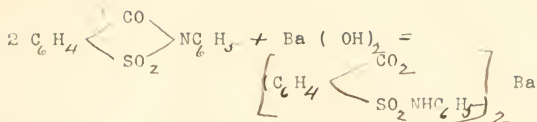


The anil under the influence of alkalis was shown to pass to salts of (o) phenylsulphaminebenzoic acid, the reaction being simply one of hydrolysis:

-----  
(1) Loc. cit.



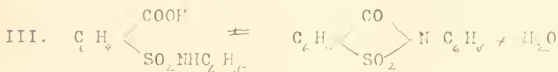
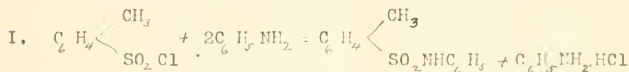




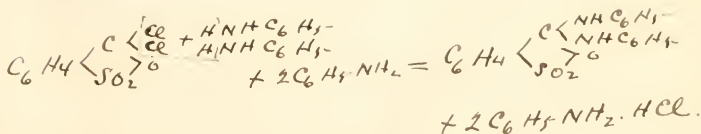
From the barium salt was prepared the free acid.

(1)

Remsen and Kohler strengthened the conclusions previously stated, by passing from orthotoluenesulphone chloride, through orthotoluenesulphone anilide and orthosulphaminebenzoic acid, to orthosulphobenzonic anil, according to the following reactions:



The unsymmetrical or liquid chloride as it was called by the earlier workers in this field gave with aniline (2) an infusible anilide, to which the unsymmetrical formula was assigned:



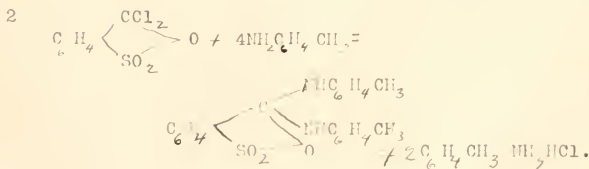
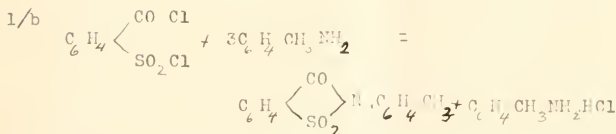
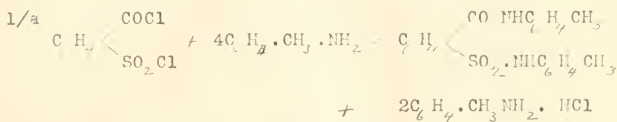
(1) Loc. cit.

(2) Remsen and Coates, Amer.Chem.Jour., 17, 311.



## II. ACTION OF TOLUIDINE -

In a similar manner toluidine yields the fusible toluidide and tolil with the symmetrical chloride, and the infusible toluidide with the unsymmetrical chloride.



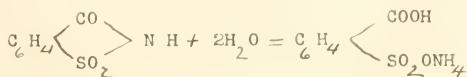


In order that such compounds might be further studied and with the idea of adding something to our knowledge of the two isomeric chlorides of orthosulphobenzoic acid, it was suggested that I study their action on the primary and secondary amines of the aliphatic series. This paper contains the results of such work.

#### PREPARATION OF MATERIAL.

Benzoic sulphinide was the starting point for the preparation of the two isomeric chlorides, by methods that in the main have been worked out in this laboratory. There are involved in the preparation of the symmetrical chloride five distinct operations:

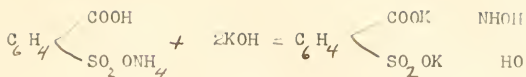
I. HYDROLYSIS OF BENZOIC SULPHINIDE, with the formation of the acid ammonium salt of orthosulphobenzoic acid:



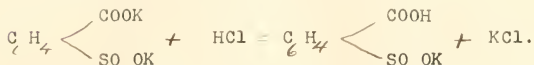
II. PREPARATION OF THE NEUTRAL POTASSIUM ORTHOSULPHOBENZOATE:







III. TRANSFORMATION OF THE NEUTRAL POTASSIUM SALT INTO THE ACID POTASSIUM SALT:



IV. THE TREATMENT OF THE DRY ACID POTASSIUM SALT OF ORTHOSULPHOBENZOIC ACID WITH PHOSPHORUS PENTACHLORIDE.

A mixture of the unsymmetrical and symmetrical chlorides is found, the former being subsequently decomposed by ammonia into ammonium orthocyanbenzenesulphonate.

V. CRYSTALLIZATION OF THE CRUDE CHLORIDE FROM PETROLEUM ETHER.

Only the unsymmetrical chloride is formed when neutral potassium orthosulphobenzoate is heated in sealed tubes with phosphorus oxychloride. Like the symmetrical chloride the unsymmetrical chloride is finally purified by crystallizing it from



ACID AMMONIUM SALT OF ORTHOSULPHOBENZOIC ACID.

One hundred grams of benzoic sulphinide (saccharin) are added to an aqueous solution of hydrochloric acid, prepared by diluting 125 c.c. of chemically pure concentrated hydrochloric acid with one and one-half litres of distilled water. The mixture is boiled until the benzoic sulphinide is completely hydrolyzed. The passing into solution of the benzoic sulphinide is indicative of partial hydrolysis, as benzoic sulphinide itself is but slightly soluble in water and practically insoluble in dilute hydrochloric acid. An absolute criterion as to the end of the reaction is the disappearance of the sweet taste of the solution of the acid ammonium salt. The best results are obtained when the temperature of the solution is kept near the boiling-point of water, and the solution at constant volume. The time required for the hydrolysis varies according to the conditions. Under the most favorable conditions six to eight hours continuous heating being necessary. After the complete transformation of the benzoic sulphinide into the acid ammonium salt of orthosulphobenzoic acid, the solution of the latter is exposed to one-third its original volume and allowed to cool. The acid ammonium salt crystallizes in large monoclinic plates. (1) These are filtered off and

- 
- (1) Remsen & Fahlberg, Am. Chem. Jour. I. 426.  
Remsen & Dohme, S. C. J. 11. 332.



the mother-liquor evaporated to dryness, constantly stirring the mass during the last operation. Usually the dried powdered acid ammonium salt is colored light brown, in consequence of slight decomposition by heat. It can be obtained perfectly pure by repeated washing with absolute alcohol. For this purpose the salt is placed in a large funnel and the alcohol allowed to percolate through it until colorless. The salt is dried by pressing it between filter paper or on porous plates.

#### THE ACID POTASSIUM SALT OF ORTHOSULPHOBENZOIC ACID.

To the semi-saturated solution of the acid ammonium salt of orthosulphobenzoic is added somewhat more solid potassium hydroxide than is required for the formation of the neutral salt; and the solution boiled until all the ammonia has been expelled. After cooling the solution to ordinary temperature pure concentrated hydrochloric acid is added until no farther precipitation takes place. The white precipitate is the acid potassium salt. It is filtered and the mother-liquor evaporated, not to dryness, however, for by so doing the acid potassium salt of orthosulphobenzoic acid will become contaminated with potassium chloride. The



salt is finally dried in an air-bath at 120 C.

### SYMMETRICAL CHLORIDE.

One hundred grams of the well dried and thoroughly pulverized acid potassium salt of orthosulphobenzoic acid are ground in a mortar, which has been previously heated on a water-bath, with two and one-half gram molecules (220 grams) of warm pulverized phosphorus pentachloride. An energetic reaction immediately ensues and the reacting products are soon converted into a yellow oil. Owing to the rapid escape of phosphorus oxychloride - a by-product of the reaction - in quite large quantities, the work should be done under a hood with good draft. The reaction product is heated on a water-bath for considerable time (at least two hours) with occasional stirring to remove excess of the oxychloride. The oil-like mass becomes viscid after some two hours heating. It is then transferred to a large separating-funnel containing ice-water or better simply ice at first, and washed until all the phosphorus oxychloride has been decomposed, and any unchanged acid potassium salt removed. The mixture of the two chlorides which are formed in the above process is taken up by cold ether in the separating-funnel, and concentrated ammonia added until the





odor of ammonia can be detected. The ammonia is added slowly, the funnel being shaken at frequent intervals. As previously stated the unsymmetrical chloride is entirely destroyed, being transformed into the ammonium salt of orthocyanbenzenesulphonic acid, which is soluble in water, and can be isolated together with potassium and ammonium chloride by evaporating the wash liquor. The symmetrical chloride is but slightly attacked in the cold. The ammoniacal solution is allowed to stand for a considerable length of time, preferably two or three hours, with occasional shaking in order to insure complete decomposition of the unsymmetrical chloride. The excess of ammonia is neutralized with hydrochloric acid, and the ether solution thoroughly washed. At least six changes of water should be made; for on the complete decomposition of the unsymmetrical chloride and the thoroughness of the subsequent washings depends the success of the operation. The ether solution of the symmetrical chloride is separated from the cold water, and dried over calcium chloride. The dry solution of the chloride is separated from the calcium chloride, and the ether distilled, when the symmetrical chloride remains in the flask. On shaking the flask the chloride crystallizes in white needles, that melt at 78 C - one and one-



half degree lower than the pure product providing the previous washings have been thorough enough. The chloride is finally obtained in an absolute degree of purity by crystallizing it one or more times from ligroin, which in turn has been especially purified. The process used in purifying the ligroin, will be described later. The pure symmetrical chloride melts at  $79^{\circ}5$  C. It can be kept almost indefinitely in a well stoppered bottle which in turn is kept in a sulphuric acid desiccator.

#### THE UNSYMMETRICAL CHLORIDE.

The neutral potassium salt is intimately mixed with one and one-half gram molecules of phosphorus oxy-chloride, the mixture enclosed in sealed glass tubes and heated not higher than  $135^{\circ}\text{C}$ ,<sup>(1)</sup> for above this temperature orthochlorobenzoyl chloride,  $\text{C}_6\text{H}_4 \begin{matrix} \text{Cl} \\ \swarrow \\ \text{COCl} \end{matrix}$ , is formed. It was accidentally discovered that the temperature can be raised as high as  $170^{\circ}\text{C}$  without any appreciable quantity of the orthochlorobenzoylchloride being formed, providing the temperature is immediately lowered. The mixture should be subjected to

---

(1) Humphreys, Inaug. Diss. J.U.W., 1900.



heat of  $135^{\circ}\text{C}$  for not less than eight hours. A maximum yield was obtained when the temperature was carefully regulated ( $130^{\circ} - 135^{\circ}$ ) for fourteen hours. After cooling the tubes are broken and the resulting product treated with ied water, to remove any excess of phosphorus oxychloride, potassium chloride and any unchanged neutral potassium salt. After thoroughly washing the chloride it is pressed out on porous plates and hastily dried, and finally crystallized from ligroin. Two or more crystallizations were found to be necessary for the complete purification of the unsymmetrical chloride. Its melting-point when pure is  $39^{\circ} - 40^{\circ}$ . Prior to 1898 a mixture of the two isomeric chlorides, that crystallized in fairly good form and melted sharply at  $21^{\circ}\text{C}$  (1) was thought to be a chemical individual.

PURIFICATION OF PETROLEUM ETHER (LIGROIN) AND  
CRYSTALLIZATION OF THE CHLORIDES.

It has been found in this laboratory that the chlorides are obtained in best condition by crystallizing them from high boiling ligroin, boiling-point  $90^{\circ} - 125^{\circ}$ . Com-

---

(1) List and Stein. Ber. d. Chem. Ges. 31, 1653.



mercial ligroin does not suffice, as it contains impurities which invariably come out with the chloride. The ligroin is therefore purified as follows: It is shaken in contact with pure concentrated sulphuric acid with a mechanical agitator for eight or ten days, that is, until a fresh supply of acid is changed only a light straw color, after several minutes shaking. If on the other hand the ligroin is allowed to stand in contact with sulphuric acid for several months very little or no shaking will be required. The acid is separated from the ligroin, the latter washed, first with water, then with warm dilute solution of potassium hydroxide, and finally, with warm water. It is preserved over calcium chloride in glass-stoppered bottles.

Considerable more chloride than will dissolve in a given amount of ligroin is heated in a suitable flask on a water-bath to a temperature not exceeding  $35^{\circ}\text{C}$  for the unsymmetrical chloride. The solution is filtered or carefully decanted and allowed to cool. If the temperature is lowered slowly, quite large crystals can be obtained. In order to facilitate the work the chloride can be frozen from the solution with salt and ice. The ligroin is poured from the crystalline product and the operation repeated. By thus proceeding a few hundred cubic centimeters suffice





for the crystallization of a large amount of the chloride.

#### METHOD EMPLOYED IN HANDLING THE AMINES.

The methyl - and dimethylamines were obtained from the corresponding hydrochlorides by treating a concentrated aqueous solution of the latter with solid potassium hydroxide, this being used rather than the sodium hydroxide because of its greater solubility. In the majority of the experiments the employment of the dry amine was necessary. The drying of the gases was accomplished by passing them through one or more Peligot tubes filled with finely pulverized sodium or potassium hydroxide. In cases where the anhydrous gas was not needed, the amine was passed directly from the generator into a vessel containing the chloride or into water, and afterwards used in form of the aqueous solution.

Ethylamine was obtained from Kahlbaum, Berlin, in anhydrous condition, sealed in stout glass vessels, as its boiling-point is  $17^{\circ}.5$  C. Since the liquid amine was needed only in connection with a few experiments, it was kept as 20 per cent aqueous solution, from which the amine was liberated as desired by adding solid potash.



ACTION OF METHYLAMINE ON THE CHLORIDES OF  
ORTHO-SULPHOBENZOIC ACID.  
SYMMETRICAL CHLORIDE.

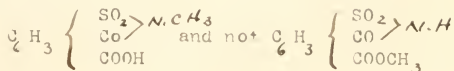
As has been pointed out, substituted ammonias of the aromatic series yield two classes of compounds according to the conditions of the reactions. Aniline, for example, gives rise to the dianilide and the anil. Methylamine and the symmetrical chloride, on the other hand, form only one compound, namely, the methyl ester of benzoic sulphinide.

(1)

In 1884 Remsen and Stokes, continuing the work of  
 (2)  
 Remsen and Comstock, prepared and described the mono- and di-methyl esters of phthalic sulphinide:



The monomethyl ester was obtained by treating the anhydrous acid silver salt with methyl iodide. Its characteristics were carefully studied, and it was shown to possess this structure



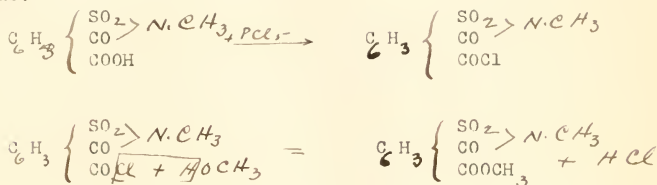
At the same time the dimethyl ester was prepared in

(1) Amer. Chem. Jour. 6, 262.

(2) Ibid. 316.



three ways, namely, from the neutral silver and lead salts, and, finally, from the monomethyl ester by treating it with phosphorus pentochloride and then with methyl alcohol, thus:-



The history of the ester of benzoic sulphinide antedates that of the chlorides of orthosulphobenzoic acid.

The first attempt to prepare methyl benzoic sulphinide recorded in the literature was by Remsen and Palmer (1886). They obtained a compound by heating silver benzoic sulphinide with methyl iodide in a pressure bottle at  $100^\circ$ , which after several crystallizations came out in concentric needles, melting at  $128^\circ - 129^\circ$ . No analysis of the compound was made.

(2)

Brackett, in the following year continued the work and prepared the methyl ester and two other esters - ethyl and propyl - one of which will be referred to later, by methods similar to that employed by Remsen and Palmer. He

(1) Amer. Chem. Jour. 8. 126.

(2) Ibid. 9, 406.



recorded the melting-point at  $131^{\circ}$ – $132^{\circ}$ , and from three sulphur determinations concluded that its formula is

$$\text{C}_6\text{H}_4 \begin{array}{c} \nearrow \text{CO} \\ \searrow \text{SO}_2 \end{array} \text{N.C.H}_3$$
 No experimental work was described, farther than the mode of preparing the compound, as evidence in favor of the above formula.

(1)

Remsen and Dohme started to continue the work of Brackett, but were attracted by other derivatives of ortho-sulphobenzoic acid. The work therefore remained in this condition until the present research was begun.

#### METHYL BENZOIC SULPHINIDE.

The methylamine, which was liberated from methylamine hydrochloride and dried by passing over solid caustic potash, was conducted into an anhydrous ether solution of the chloride. Immediately there appeared a white precipitate, that in every instance, where the temperature of the ether solution was kept below  $25^{\circ}\text{C}$  and the flow of amine properly regulated, possessed a semi-crystalline structure. Considerable difficulty was experienced in securing the

---

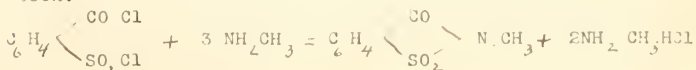
(1) Dohme, Inaug. Diss. Johns Hopkins Univ. 1889.





proper conditions for the successful performance of the experiment. For example, even though the ether solution of the chloride was lowered to  $10^{\circ}\text{C}$ , the temperature would rise very rapidly and the reaction products come out gummy, if the amine was allowed to pass rapidly into it. Methylamine hydrochloride, which was always one of the products of the reaction, was almost wholly precipitated from the solution. It carried down varying amounts of the methyl ester. It was expedient to allow the ether to evaporate at ordinary laboratory temperatures. The mixture, which, under most favorable conditions consisted of a white flocculent mass, was transferred to a funnel and washed a few times only with cold water in order to remove the methyl amine hydrochloride. Since the hydrochloride is extremely soluble in cold water, it is unnecessary to continue the washing long.

The residue was crystallized from alcohol and analyzed, and found to be the methyl ester of benzoic sulphinide. The reaction between the methyl amine and the symmetrical chloride can be represented by the following equation:





The ester was analyzed for carbon, hydrogen, sulphur and nitrogen.

0.2121	grams	gave	0.2595	grams	BaSO <sub>4</sub>
0.1149	"	"	0.2595	"	BaSO <sub>4</sub>
0.0928	"	"	0.1131	"	BaSO <sub>4</sub>
0.1354	"	"	0.0083	"	N
0.1312	"	"	0.2326	"	CO <sub>2</sub>
	"	"	0.0439	"	H <sub>2</sub> O

Calculated for

Found.

$\text{C}_6\text{H}_4 \begin{array}{c} \diagup \text{CO} \\ \diagdown \text{SO}_2 \end{array} \text{N} \cdot \text{CH}_3$		I.	II.	III.	IV.	V.
C	48.68	-----	-----	-----	-----	48.34
H	3.53	-----	-----	-----	-----	3.24
N	7.07	-----	-----	-----	6.13	----
S	16.26	16.89	16.65	16.73	-----	----

The sulphur had to be determined by the method of Liebig. Many attempts were made to oxidize the ester with fuming nitric acid, according to the method of Carius, at temperature as high as 350 C. Almost invariably a small portion of the substance would resist the action of the acid. The nitrogen was determined by the Kjeldahl method.



Methyl benzoic sulphinide is slightly soluble in hot water, melting to a colorless oil, and practically insoluble in cold water. It is quite soluble in ether, more sparingly so in absolute alcohol. From ethyl alcohol it crystallizes in fine needles, from a mixture of alcohol and water (about 60 per cent. solution) in large prisms terminating in pyramidal faces. The ester can be obtained in pure crystalline condition most easily by dissolving it in hot alcohol and adding warm water until the solution becomes cloudy, then heating on a water-bath until complete solution ensues, and allowing it to cool slowly. When pure, methyl benzoic sulphinide melts at  $129^{\circ}\text{C}$ .

BEHAVIOR OF METHYL BENZOIC SULPHOINIDE IN PRESENCE  
OF ACIDS AND ALKALIES.

-----

Sulphuric and hydrochloric acids have no action on the ester at ordinary temperatures. When boiled with the ester for 12 or 14 hours, however, aqueous hydrochloric acid hydrolyzed it, forming the acid methylammonium salt of orthosulphobenzoic acid, which crystallized in concentric

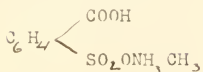


needles. One determination of sulphur indicated the above compound.

0.2145 grams gave 0.2152 grams  $\text{BaSO}_4$

Calculated for

Found.

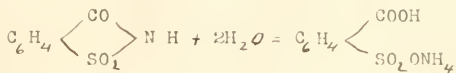


S 13.74

13.79

When the acid ammonium salt is heated with potassium hydroxide neutral potassium orthosulphobenzoate is formed, methyl amine being given off. Acid potassium salt of orthosulphobenzoic acid is precipitated on the addition of hydrochloric acid to the solution.

The formation of the acid methylammonium salt is in every way analogous to the action of hydrochloric acid on benzoic sulphinid:



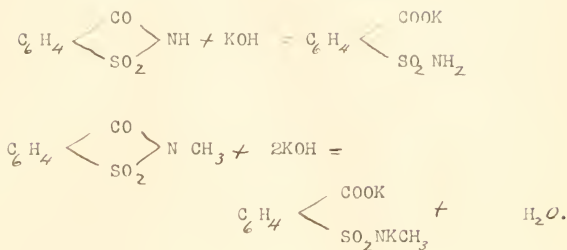
Just as benzoic sulphinide is converted into orthosulphaminebenzoic acid by boiling with a dilute solution





(1)

of potassium hydrozide, so the methyl ester is hydrolyzed to orthomethylsulphaminebenzoic acid:



One essential difference is to be noted, however. Aqueous alkalies do not effect the transformation; alcoholic alkalies being necessary, and even then five or six hours are required for the complete hydrolysis. It is of interest to note also that the alkali metals form the dimetalic salts, while the metals of the alkaline earths replace only the hydrogen of the carboxyl group.

Potassium orthomethylsulphaminebenzoate crystallizes from alcohol in small plates. It is extremely soluble in water, and alcohol, insoluble in ligroin.

0.1875 grams gave 0.1121 grams  $\text{K}_2\text{SO}_4$

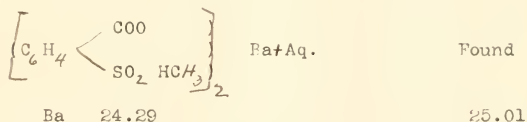
Calculated for

		$\text{C}_6\text{H}_4 \begin{array}{c} \text{COOK} \\ \diagup \quad \diagdown \\ \text{SO}_2 \text{NKCH}_3 \end{array}$	
K	26.27		Found 28.35

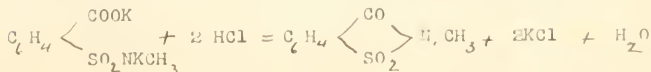


Barium hydroxide and the methyl ester give the barium salt of orthosulphaminebenzoic acid. It was so very soluble in water and alcohol that no crystals of it were obtained. From a mixture of methyl alcohol and water an amorphous powder was obtained, from which two determinations of barium were made

0.3014 grams gave 0.1281 grams  $\text{BaSO}_4$   
calculated for

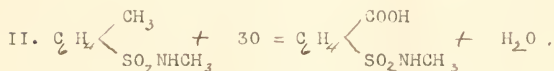
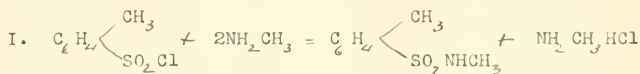


From the barium and potassium salts of (O) methylsulphaminebenzoic acid, attempts were made to secure the free orthomethylsulphaminebenzoic acid. The acid was especially desired, for it was hoped that it would form one of the links of the chain, the starting of which was methyl benzoic sulphimide and the ending the same compound. The intermediate compound, that is, the free acid, was not obtained in this connection; the ester was formed at once:

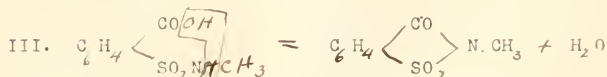




The question now presented itself, Is the hydrolyzed ester the methylsulphaminebenzoic acid? In order to answer this question satisfactorily, another method of preparation was employed. By treating the chloride with methylamine it was thought that orthomethyltoluenesulphone amide would be formed, and from this by oxydizing with alkaline potassium permanganate orthomethylsulphaminebenzoic acid.



And the acid by dehydration would pass to ethyl benzoic sulphinide.



Orthotoluenesulphone chloride was treated with a strong aqueous solution of methylamine. In the presence of large excess of the aqueous amine, the methyltoluenesulphone amide remains in a semi-solid condition, so that one is quite easily misled as to the end of the reaction. The solution was cooled with iced water and the amide separated by filtration. Orthomethyltoluenesulphone amide was found to be insoluble in cold water, slightly soluble in hot wa-



ter, quite soluble in absolute alcohol, but from the last it did not crystallize in good condition. It is also soluble in acetone and chloroform; thin striated plates crystallizing from the former (melting-point  $73^{\circ}\text{C}$  -  $75^{\circ}\text{C}$ ). Further, the methyl amide was found to be extremely insoluble in benzene, and almost insoluble in cold ligroin; a mixture of these two solvents furnishes the best medium from which to crystallize it. The impurities are less soluble in benzene than the methylanide itself, and are totally insoluble in ligroin. The impure (O) methyltoluenesulphone amide was desolved in an excess of benzene and ligroin added until the liquid became milk-white. The mixture was then heated on a water-bath until clear. The impurities collected at the bottom of the vessel in the form of a dark brown oil, from which the supernatant solution was poured. If the proper amount of ligroin is added the amide comes out in beautiful colorless needles after one crystallization. Slow crystallization gives rise to plates rapid, to needles. The melting-point of both products is  $74^{\circ}$ - $75^{\circ}\text{C}$ .





I.	0.1969	grams	gave	0.2510	grams	BaSO <sub>4</sub>	(Liebig's method)
II.	0.2033	"	"	0.2550	"	BaSO <sub>4</sub>	"
				(0.3739			
III.	0.2033	"	"	(	"	CO <sub>2</sub>	
				(0.1038		H <sub>2</sub> O	
				(0.4186	"	CO <sub>2</sub>	
IV.	0.2216	"	"	(			
				(0.1191	"	H <sub>2</sub> O	

	<u>Calculated for</u>			<u>Found</u>		
	$\text{C}_6\text{H}_4 \begin{array}{l} \text{CH}_3 \\ \diagup \\ \text{SO}_2\text{NHC}_2\text{H}_5 \end{array}$					
	I	II	III.	IV.	V.	
S	17.31	17.45	16.92	-----	-----	-----
C	51.77	-----	-----	52.12	51.51	
H	6.06	-----	-----	5.94	6.01	

The pure orthomethyltoluenesulphone amide was oxidized by potassium permanganate in alkaline solution in the usual manner.

This oxidation gave rise to the formation of a small amount of the potassium salt of orthomethylsulphaminebenzoic acid, which on acidifying with hydrochloric acid at ordinary temperatures passed to the methylester of benzoic sulphinide. However, when the temperature of the solution



was lowered to about 10 C, the acid added cautiously, and the resulting solution allowed to evaporate slowly, orthomethylsulphaminebenzoic acid crystallized in small radiating needles. The acid has no constant melting-point; softens at 70°C and is not reduced to a clear liquid below 126°C. If the temperature is kept at the latter point for some minutes, and allowed to decrease slowly, the product remaining in the tube will melt at 127°C - 129°C which indicates the formation of methyl benzoic sulphinide from the orthomethylsulphamine benzoic acid by the loss of one molecule of water.

Two unidentified products were formed, one melting at 68° - 72°C, which may have been some unoxidized<sup>(c)</sup> methyltoluenesulphone amide; the other melting not sharply at 125° - 135° crystallized in long needles. A further study of these compounds was not made, owing to lack of time.

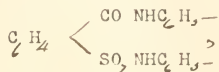
#### ACTION OF AQUEOUS AMINE ON THE SYMMETRICAL CHLORIDE.

-----

When a twenty per cent. aqueous solution of methylamine is added to the pure symmetrical chloride, reaction begins at ordinary temperatures, with the formation of



methyl benzoic sulphinide and methylamine hydrochloride. At low temperatures there was formed a second compound, crystallizing in needles (melting-point  $74^{\circ}\text{C}$ ), which is doubtless the symmetrical dimethylamide orthosulphobenzoic acid,

$$\text{C}_6\text{H}_4 \begin{cases} \text{CO NHCH}_3, \\ \text{SO}_2 \text{NHCH}_3, \end{cases} \text{ analogous to the symmetrical dianilide,}$$


which has been fully described by other investigators. The product melting at  $74^{\circ}\text{C}$  was obtained in insufficient quantities for analyzing.

If small portions of the chloride are added to comparatively large quantities of the aqueous solution of methylamine, which has been cooled to  $15^{\circ}\text{C}$ , no action takes place, nor is there any appreciable change before the temperature of the solution reaches  $20^{\circ}\text{C}$ . At this temperature a slow reaction begins and proceeds with increasing violence and rapidity unless the vessel is plunged into the cooling mixture. In almost every instance the heat of the reaction was sufficiently intense to melt the chloride.



## UNSYMMETRICAL CHLORIDE

-----

The unsymmetrical chloride of orthosulphobenzoic acid in anhydrous ether solution was subjected to the action of methylamine in essentially the same manner as was the symmetrical chloride. When the amine was passed rapidly into the solution of the unsymmetrical chloride, the temperature was soon raised to the melting-point of the chloride and boiling-point of the ether. The ether, saturated with methylamine vapors, carried over small quantities of the chloride, which on coming in contact with the air presented a white cloud-like appearance. The chloride was shown to be present by a simple experiment. The white vapors which were somewhat heavier than air were allowed to pass into a beaker, partially filled with water. An oil collected on the surface of the water, which proved to be the unsymmetrical chloride.

The reaction products were handled differently according to circumstances. For example, when the end product was viscous, both the desired product and methylamine hydrochloride, which is always a by-product of the reaction were dissolved in anhydrous alcohol and attempts were made to separate them by fractional crystallizations. These at-





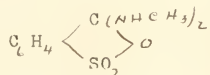
tempts were not entirely successful as will be shown later. However, when the reaction continued smoothly and the hydrochloride was precipitated in dry flaky condition, the entire product, after the evaporation of the ether at ordinary temperatures, was washed with iced-water, to remove the methylamine hydrochloride. The residue is quickly pressed between filter papers and thoroughly dried. There are formed at least two compounds when methylamine acts on the unsymmetrical chloride. On dissolving the dry reaction-product in anhydrous alcohol by heat, the methyl ester of benzoic sulphinide crystallized out of the cold solution. The ester was also formed, and in somewhat larger quantities, when the reaction-product was dissolved in dilute alcohol. Methyl benzoic sulphinide as thus obtained was found to be identical with that from the symmetrical chloride and methylamine. The other compound proved to be the unsymmetrical dimethylamide of orthosulphobenzoic acid.

Tautomerism is particularly noticeable when the reaction-product is heated with alcohol and water, there being formed at times as much as 15 per cent. of the methyl benzoic sulphinide, which invariably crystallizes first, and can be separated from the syrupy mass by means of a Witt plate and filter pump. Rarely did there crystallize



from the remaining syrup any of the unsymmetrical derivative. On the other hand, it was obtained more frequently when the reaction-product from the methylamine and unsymmetrical chloride was dissolved in an excess of anhydrous ethyl alcohol at ordinary temperatures, and the solvent evaporated by passing a current of dry air over the solution, or by allowing the solution to remain in a sulphuric acid desiccator until crystallization was complete.

Infusible dimethylamide of orthosulphobenzoic acid,



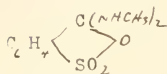
is obtained as stated above, by the action of methylamine on the unsymmetrical chloride at low temperatures. It crystallizes from alcohol in plates, which are insoluble in cold water. In fact the best method for obtaining the crystals free from the mother-liquor is to wash them thoroughly with water. The amide does not fuse at 330°C, above this temperature decomposition begins. The following analytical results for carbon and hydrogen were obtained.



0.2531 grams gave 0.4418 grams  $\text{CO}_2$

and 0.1231 "  $\text{H}_2\text{O}$ .

Calculated for



Found

C	47.75	47.60
H	5.55	5.46

Evidently this compound is isomeric with the anilide of the formula



As has been stated, such a derivative has not been isolated.

In order that a false impression will not be got from the description just given, it might be advisable to say that the products of the action of methylamine on the unsymmetrical chloride are not easily obtained, neither can they be isolated in large quantities. By far the greatest proportion of the reaction-products are non-crystallizable, remaining in a syrupy condition even after standing for three months.



ACTION OF ETHYLAMINE ON THE CHLORIDES OF ORTHOSUL-  
PHOBENZOIC ACID.

HISTORICAL -

(1)

Remsen and Fahlberg mention for the first time attempts to prepare ethyl benzoic sulphinide. They passed hydrochloric into an alcoholic solution of benzoic sulphinide without detecting any formation of the ethyl ester.

In 1888 R. N. Brackett, working in this laboratory, prepared the ethyl ester of benzoic sulphinide by heating silver benzoic sulphinide with ethyl iodide. He describes two compounds formed in the reaction, one melting at  $83^{\circ}$  -  $84^{\circ}$  and the other at  $96^{\circ}$  -  $97^{\circ}$ . No detailed study was made of either compound, nor indeed were there any analyses made. A short time previous to the publication of Brackett's results,

(2)

Fahlberg and List presented a paper to the German Chemical Society on "Benzoic Sulphinide and Orthosulphaminebenzoic acid", in which they describe quite accurately the ethyl ester of benzoic sulphinide, having prepared it by heating sodium benzoic sulphinide with ethyl io-

---

(1) Amer. Chem. Jour. 1. 426.

(2) Ibid. 9. 406.

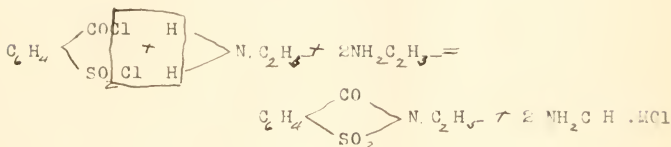
(3) Ber. d. deutsch. Chem. Ges. 20. 1598. (1887).





dide for several hours at 230<sup>U</sup> C. The yield, as stated by them, was quantitative.

SYMMETRICAL CHLORIDE.— Ethyl benzoic sulphinide is the sole product of the action of anhydrous ethylamine on the dry ethereal solution of the symmetrical chloride:



The ethyl ester was isolated as was the methyl ester namely, by extracting the methyl amine hydrochloride from the white pulverulent residue obtained from the ether solution, with cold water, and crystallizing the ethyl derivative from alcohol. It is soluble in ethyl alcohol, less so in methyl alcohol, quite soluble in acetone, benzene, slightly soluble in ligroin and warm water, and practically insoluble in cold water. Ethyl benzoic sulphinide crystallizes from dilute alcohol in acicular crystals and from anhydrous alcohol in stout prisms, melting at 94<sup>(1)</sup>.

---

(1) The properties of Ethyl benzoic sulphinide were found identically as given by Fahlberg and List. Loc cit.

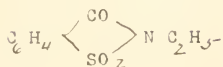


It was analyzed with the following results.

I.	0.0417	grams	gave	0.0503	grams	BaSO <sub>4</sub>	(Liebig's Method)
II.	0.0964	"	"	0.1171	"	BaSO <sub>4</sub>	
III.	0.1737	"	"	0.2045	"	BaSO <sub>4</sub>	"
IV.	0.2158	"	"	( 0.4062	"	CO <sub>2</sub>	
				( 0.0812	"	H <sub>2</sub> O	
V.	0.3012	"	"	( 0.6415	"	CO <sub>2</sub>	
				( 0.1103	"	H <sub>2</sub> O	
VI.	0.1975	"	"	0.0156	"	NH <sub>3</sub>	( )
VII.	0.2004	"	"	0.0163	"	NH <sub>3</sub>	

Theory for

Found

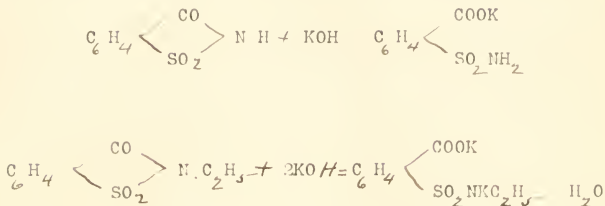


	I	II.	III.	IV.	V.	VI.	VII.
S 16.28	16.57	16.77	16.18	----	----	----	----
C 51.31	----	----	----	51.34	51.29	----	----
H 4.25	-----	-----	----	4.19	4.14	----	----
N 6.63	-----	----	----	----	----	6.59	6.67

-----



Ethyl benzoic sulphinide passes to ethylsulphamine-benzoic acid by hydrolysis with alcoholic potash.



The neutral potassium salt crystallizes from water in very small plates, which are extremely soluble in water. Two determinations of the water of crystallization indicated two molecules. The anhydrous salt when heated with sulphuric acid yielded the following results:

0.2005 grams gave 0.0992 grams  $\text{K}_2\text{SO}_4$

0.2851 " " 0.1415 "  $\text{K}_2\text{SO}_4$

Theory for

Found



I.

II.

K 22.11

22.21

22.31

By heating the ethyl ester of benzoic sulphinide in a retort connected with a reflux condenser, for six hours, with alcoholic barium hydroxide, barium orthomethylsulpha-

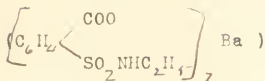


minebenzoate was obtained.

0.5102 grams gave 0.0951 grams  $\text{BaSO}_4$

Theory for

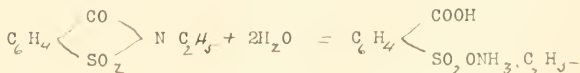
Found



Ba 23.21

23.29

It is necessary to heat the ethyl ester for two days with dilute hydrochloric acid in order to completely transform it into the ethylammonium salt of orthosulphobenzoic acid. The reaction is exactly similar to the hydrolysis of benzoic sulphinide and of the methyl ester by hydrochloric acid:

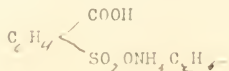


The ethylammonium salt crystallizes from water in delicate needles. One determination of sulphur was made.

0.2154 grams gave 0.2053 grams  $\text{BaSO}_4$  (L.M)

Found

Calculated for



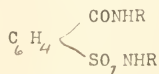
S 13.1

12.96





Since ethylamine boils at 17.5° C and as has been stated it was obtained in the anhydrous condition, it seemed desirable to try the action of the liquid amine on the symmetrical chloride, particularly at low temperatures. At 20° C. an excess of the liquid amine has no action on the chloride; at or near 15° C. an energetic reaction takes place, with the formation principally of the ethyl ester of benzoic sulphimide. Usually, however, the liquid amine reacted with the chloride so violently that the end-product consisted of a gummy uninviting mass, from which little could be obtained. No compound was isolated that involved the action of two molecules of the amine to one of the symmetrical chloride, that is of the general formula



UNSYMMETRICAL CHLORIDE - Ethylamine, like methylamine reacts at least in two ways with the unsymmetrical chloride. First, with the formation of the symmetrical derivative; secondly, with formation of the infusible diethylamide of orthosulphobenzoic acid. When the reaction-product is heated with dilute alcohol ethyl benzoic sulphinide is form-



ed in somewhat larger quantities than was formed in connection with the methyl ester. One crystallization only was necessary to bring the melting-point of the ethyl ester to that of the product obtained from the symmetrical chloride ( $94^{\circ}\text{C}$ ). There is no danger of mistaking the ester. It is perfectly characteristic in all its reaction.

Although these reactions - of methyl- and ethylamine with the unsymmetrical chloride - are seemingly analogous in every way, there is a larger percentage of the ethyl ester formed. Experiments carried out under comparable conditions - temperature of the solution, rate of flow of the amine, dilution of the alcohol, etc. - substantiates this statement. And, too, the ethyl ester can be removed from the reaction-products with less difficulty than in case of the methyl ester.

The second product of the reaction of ethylamine and the unsymmetrical chloride, or probably it is more nearly correct to say the crystallizable portion obtained from anhydrous solvents (generally alcohol), was infusible diethylamide of orthosulphobenzoic acid. The infusible diamide was obtained by evaporating slowly the solution of the reaction-products, from which the ethylamine hydrochloride had not been removed. The largest and most satisfactory crys-



tals were obtained from an alcoholic solution that required more than two months for the evaporation of the solvent - about 150 c.c.

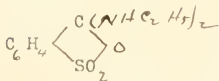
The infusible diethylamide of orthosulphobenzoic acid crystallizes in beautiful rhombic prisms, which are insoluble in petroleum ether and chloroform; sparingly soluble in benzene and acetone; reasonably soluble in methyl and ethyl alcohols, to a less degree in the former; and insoluble in water.

It yielded the following results when analyzed for carbon and hydrogen.

0.2754 grams gave 0.1469 grams  $H_2O$   
and 0.4991 "  $CO_2$

Calculated for

Found



C 49.53

49.41

H 6.56

6.98

Liquid ethylamine was treated with the unsymmetrical chloride under varying conditions. At temperature at or near 15 C, they react so energetically that the end-pro-



ducts could not be identified. The ethylamine was very rapidly evaporated and carried off with it small particles of the chloride, the appearance of the vapor being the same as described in connection with the reaction of methylamine and the unsymmetrical chloride.

At  $0^{\circ}\text{C}$  or slightly above this temperature, the liquid ethylamine reacts with the unsymmetrical chloride quite satisfactorily. The product which was slightly colored yellow, was freed from the ethylamine hydrochloride by washing with ice cold water. The only compound that was certainly identified was the ethyl ester of benzoic sulphinide. At  $-20^{\circ}\text{C}$  anhydrous ethylamine is entirely without action on the unsymmetrical chloride.





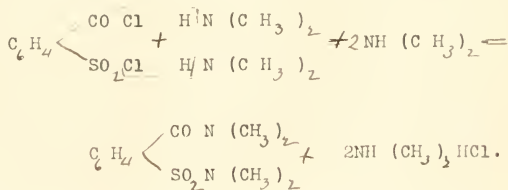
THE ACTION OF A SECONDARY AMINE -  
 DIMETHYLAMINE - ON THE CHLORIDES OF  
 ORTHOSULPHOBENZOIC ACID.

-----

SYMMETRICAL CHLORIDES.

--oo--

The symmetrical chloride is quantitatively transformed into the symmetrical tetramethyldiamide of ortho-sulphobenzoic acid by dimethyl amine in anhydrous ether solution, according to the following equation:



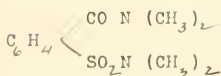
Of all the products thus far obtained this one crystallizes best. Alcohol was found to be the best solvent from which to crystallize it.

The pure tetramethylorthosulphaminebenzamide( ) yielded the following results on analysis.



I.	0.2143	grams	gave	0.2082	grams	of	Ba SO <sub>4</sub> .
II.	0.1978	"	"	0.2082	"	"	Ba SO <sub>4</sub> .
III.	0.2396	"	"	( 0.4345	"	"	CO <sub>2</sub>
				( 0.1424	"	"	H <sub>2</sub> O
				(0.5162	"	"	CO <sub>2</sub>
IV.	0.2851	"	"	(	"	"	
				(0.1703	"	"	H <sub>2</sub> O
V.	0.1590	"	"	0.0195	"	"	N.
IV.	0.2508	"	"	0.0285	"	"	N.

Theory for

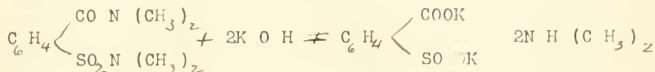


S	13.01	13.25	13.44	----	----	----	----
C	49.53	-----	-----	49.72	49.37	----	----
H	6.56	----	----	6.66	6.67	----	----
N	11.37	----	----	-----	----	12.26	11.38

Unlike the esters of benzoic sulphinide, tetramethyl-orthosulphaminebenzamide is not changes by alcoholic caustic alkalies; like the esters it is not decomposed by dilute aqueous caustic alkalies. Concentrated aqueous alka-



lies give rise to the corresponding salt of orthosulphobenzoic acid and dimethylamine.



Dilute mineral acids do not hydrolyze the compound  
(1)

Crystallographic examination of a few of the more nearly perfectly formed crystals of tetramethylorthosulphaminebenzamid was undertaken and the following results obtained:

The crystals were found to be of two habits, both tabular parallel to the front pinacoid (100), but differing in the presence or absence of the front pinacoid. The crystals are simple and show but few faces, as indicated in the accompanying figures. Figs. I. and II. are front and back views of the same crystal and Fig. III. is of the other type.

Faces A and E were imperfect, showing many small cavities due to etching or incomplete growth. Faces L and I, which were striated parallel to the edge L I, were large

---

(1) The crystallographic work herein described was done by Dr. E. B. Matthews, and Mr. A. Johannsen.



and extended almost entirely across the crystals, giving them a monoclinic appearance. The edges I B and L H were so imperfect that they could not be used in measurements. Faces J and K were very small and their edges against the pinacoidal faces were indistinct, rendering measurements of these angles impossible.

The average of the angles observed were as follows:

$H \wedge A, A \wedge B, D \wedge E, D \wedge F = 12\ 30'$ . Range of readings  $9'$ .

$B \wedge C, C \wedge D, F \wedge G, G \wedge H = 77\ 30$  "  $17'$ .

$B \wedge H, F \wedge D = 25\ 00$

$I \wedge J = 60\ 35$

$J \wedge D = 44\ 12$

$C \wedge I = 73.25$

$I \wedge A, L \wedge A = 70\ 20$

$L \wedge I = 32\ 10$

$J \wedge E, K \wedge E, I \wedge B$ , and  $L \wedge H$  were indeterminate.

The foregoing measurements did not clearly prove the monoclinic or orthorhombic character of the crystals, but optical tests showed parallel extinction with the emergence of a bisectrix in section parallel to A. The extinction shown when the crystal was examined parallel to C was also parallel. The plane of the optic axes was perpendicular to the tabular face. From the parallel extinction in two di-





rections it is concluded that the crystals are orthorhombic, though the conclusion is neither proved nor disproved by the crystal measurements. On the assumption that the crystals are orthorhombic the following crystallographic constants are found:

Axial ratio,  $a : b : c$        $0.232 : 1 : 0.127$



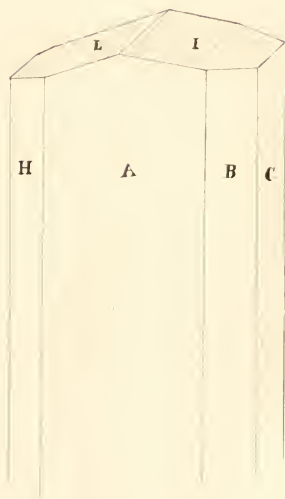
*Fig. I.*



Fig II

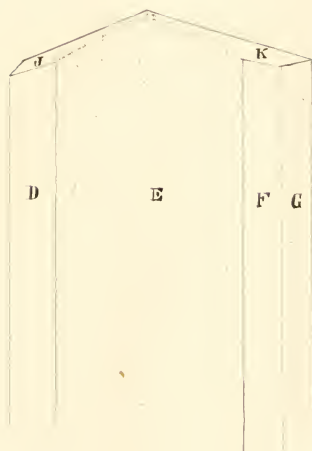




Fig. 10.







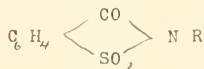
UNSYMMETRICAL CHLORIDE - The only product of the action of dimethylamine on the unsymmetrical chloride that was isolated was the compound obtained from the symmetrical chloride. This change from unsymmetrical to symmetrical derivative was more apparent than in any case particularly considered. No infusible product, corresponding to the primary amine derivative were isolated.



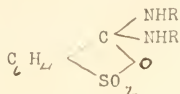
## CONCLUSIONS.

This investigation has shown

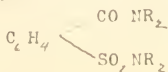
- I. That the symmetrical and unsymmetrical chlorides of orthosulphobenzoic acid can be obtained absolutely pure by crystallizing them once from pure ligroin, providing the previous washings are thorough.
- II. That the symmetrical chloride reacts with primary amines with the formation of esters of benzoic sulphinide of the general formula



- III. That the unsymmetrical chloride with primary amines yields small amounts of the esters of benzoic sulphinide, together with infusible di-substituted amides.



- IV. That the secondary amines react normally with the symmetrical chloride, giving rise to compounds of the general formula





V. We have further confirmed the work of previous workers in this laboratory, showing that the two isomeric chlorides do not present any evidence of tautomerism (1) in themselves, as has been stated by List and Stein; but, that unsymmetrical derivatives possess a tendency to pass to the symmetrical form under certain conditions.

---

(1) Ber. d. Chem. Ges. 31, 1648 (1898).



### Biographical Sketch.

-----

The author was born in New Martinsville, Wetzel county, West Virginia, on August 21, 1876. His early education was obtained in the Public Schools of his native town. In 1894 he entered the West Virginia University from which he was graduated in June, 1898, with the degree of Bachelor of Science. Since the fall of the same year he has been a graduate student in Chemistry and Geology in the Johns Hopkins University.























